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Original Article

Aerobic training during hemodialysis improves body composition, muscle function, physical performance, and quality of life in chronic kidney disease patients

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Abstract. [Purpose] We assessed the influences of individualized aerobic training on body composition, knee joint muscle function, physical performance, and quality of life in chronic kidney disease patients. [Subjects] Ten chronic kidney disease patients undergoing dialysis. [Methods] Overall physical function and quality of life before and after 12 weeks of aerobic training were evaluated by body composition, the six-minute walk test, cardiopulmonary exercise tests, and Short Form 36-item questionnaire. [Results] The six-minute walk test distance increased significantly after 12 weeks aerobic training. Resting metabolic rate, lactate threshold, maximum oxygen uptake, and quality of life tended to increase after training. Post-training weight, muscle mass, body fat mass, fat percentage, body mass index, and peak torque of right and left knee extension and flexion did not change significantly. [Conclusion] Intra-dialytic training can a safe approach to maintain or improve physical performance and quality of life of chronic kidney disease patients undergoing hemodialysis without adverse events or negative cardiovascular responses. Aerobic training may prevent a decline in body composition and knee joint muscle function due to inactivity in chronic kidney disease patients. Clinically, aerobic training may initially be adapted to maintain overall physical function or improve quality of life in chronic kidney disease patients undergoing hemodialysis.

Key words: Aerobic training, Physical performance, Hemodialysis

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INTRODUCTION

Chronic kidney disease (CKD) is a severe health-related problem[1]. More than one million of necessitate hemodialysis (HD) and renal transplantation all over the world for the year[2]. As renal function deteriorates, finally get to the life-threatening end stage[3–5]. The usual consequences of uremic syndrome include decreased physical ability (by approximately 50%), diminished quality of life (QOL), and increased cardiovascular disease[6–9].

Dialysis interventions are generally performed three times per week for 4–6 hours per session. This causes HD patients to have a monotonous and restricted daily life, limiting their activities after treatment onset as well as contributing to and supporting sedentary habits, functional disability, and inactivity[6]. Activity limitations are often caused by muscle atrophy, which affects 18–80% of patients undergoing dialysis[10–13]. Muscle wasting is another remarkable problem and is a significant anticipator of morbidity and mortality[14]. Muscle quantity is strongly correlated with muscle strength, muscle oxygen extraction, and functional ability in HD patinets[10, 11, 15, 16]. In rare cases, the quadriceps tendon and patellar ligament are susceptible to rupture[17].

Establishing a physical activity routine for patients on dialysis has advantages such as greater willingness to engage in training, convenient scheduling, reduced boredom of dialysis sessions, and better ease of medical care. In addition, physical activity in HD patients is related with improved physical capacity and reduced blood pressure, and also contributes to improved QOL[18, 19]. However, the physical condition of HD patients limits their ability to perform high-intensity training such as resistance training[6]. Recent investigations have promoted intra-dialytic training as a beneficial intervention to enhance compliance, improve motivation, and promote the medical monitoring[3, 19]. The majority of training programs are performed between dialysis sessions. Therefore, this study assessed the impacts of individualized aerobic training programs supervised and carried out during dialysis sessions on body composition, muscle function of the knee joint, physical performance, and QOL in HD patients.

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SUBJECTS AND METHODS

Ten CKD patients who were undergoing maintenance dialysis in the outpatient HD unit were enrolled. The institutional review board approved all procedures. They were evaluated for eligibility based on review of medical history and physical examination. The inclusion criteria contains: older patient; during dialysis for more than three months; approval from physician; independent ambulation for at least 50 m, and properly dialyzed and stable during dialysis.

A single-group interventional study design was used to confirm the influence of aerobic training in HD patients. Body composition, muscle function of the knee joint, physical performance, and QOL were evaluated. After these assessments, the patients underwent supervised aerobic capacity during dialysis sessions for 12 weeks. These variables were re-assessed in the post-training phase.

Training consisted of a warm-up, aerobic training on a stationary bicycle, and a cool-down. For the warm-up, patients performed passive stretching of the lower limbs and aerobic activity on the bicycle at 0.5 km/h (approximately 35 rpm), which is the lowest load applicable to the ergometer (700r recumbent bike, Cybex, Boston, USA) used, for 5 minutes. After the warm-up, the conditioning phase included 30 minutes of training during the first two hours of dialysis to avoid physical stress in the second half of the session when patients' hemodynamic conditions are unfavorable. Heart rate was constantly monitored using a heart rate monitor (H1 heart rate sensor, Polar, NY, USA), and blood pressure was measured at rest every five minutes during training and after the cool-down period. The cool-down consisted of two minutes on the bicycle with minimal load at 35 rpm followed by passive stretching of the lower extremity.

The prescribed training intensity was based on Borg's Perceived Exertion Scale[7]. According to this scale, patients assign a score to the intensity of fatigue ranging from 6–20 points. Every 5 minutes during the aerobic training, patients were asked about the score they would assign to their fatigue at that moment, and the bicycle load was adjusted to achieve sufficient intensity to maintain a fatigue score between 11 and 13 points, which corresponds to an intensity of "mild" to "quite hard." The rotation speed of the pedals remained close to 35 rpm to achieve stable training intensity.

The Inbody 720 (Biospace, Seoul, Korea) was used to confirm body composition calculated from weight, mass of skeletal mass, mass of body fat, percentage of body fat, and body mass index which was measured by the electrical resistance to four frequencies in each body part. The electrical resistance was measured body composition by attaching sensors on the patient in standing position.

Maximum peak torque in the knee joint was assessed using the isokinetic digital cybex system (HUMAC NORM, NY, USA); this is a noninvasive method that uses the isokinetic mode and enables reliable measurement. Both lower limbs were tested. The patient was instructed on how to perform the task each time. The test relies on flexion and extension of the legs at the knee joint with maximum force and measures maximum flexion and extension peak torque at an arc speed of 60°/s (five movements with a one-minute rest between each set).

Training testing was performed using a branching treadmill protocol with modified Bruce[7] that started at a brisk walking speed; speed increased gradually every two minutes to assure that at least four measurements were obtained between rest and peak training. Patients were instructed to exert themselves to maximum levels. When the patient was unable to keep pace with the treadmill or requested to stop, cardiac output was measured before stopping. The electrocardiogram was measured constantly for oxygen uptake (VO_2 in L/min), and cardiac output were estimated at each stage. All tests were conduct on the same day in the same order. HD patient performed the evaluations on inter-dialytic days[20].

The six-minute walk test (6MWT) was used as an index of physical endurance and was conducted before and after training. The 6MWT is reliable for establishing the physical capacity of patients with heart and respiratory insufficiency as well as patients with chronic renal failure[20]. This test can be used to assess the influence of rehabilitation, particularly for subjects in whom maximal training testing is not possible, such as elderly patients. The 6MWT was performed on the day of dialysis before the HD session. Patients walked unassisted for 25 m down the hospital corridor accompanied by a physiotherapist; they were permitted to stop to rest. The distance (m) was recorded for each patient[21].

To evaluate QOL, the SF 36-item questionnaire was used. This questionnaire has 36 items divided into eight divisions: physical function, role of physical, body pain, general health, vitality, social function, role of emotional, and mental health. Each scale is graded from 0–100. Higher grades indicate better self-perception of QOL.

The Shapiro-Wilk test was verified normality distribution of data. After verifying that the data were normally distributed, all the analyses were conducted using parametric tests. Paired t test was used to compare the values between before and after training. It was considered significantly difference when the p value was < 0.05 using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Mean age was 56.50 ± 4.48 years (males: 55.50 ± 7.96, females: 57.17 ± 5.88), and mean height was 158.08 ± 2.72 years (males: 167.23 ± 1.74, females: 151.98 ± 1.53). There were four males (40%) and six (60%) females. The number of complications ranged from one to five (Table 1).

The goal of 30 minutes of tolerance to training was achieved around the fourth week. It is worth noting that no clinical complications occurred during training; there was only one episode of absence without leave, and training was resumed at the next dialysis session.

There were no difference between before and after training in weight, muscle mass, body fat mass, fat percentage, body mass index, and peak torque of knee extension and flexion. Each post-training variable (97.4% to 103.0%) was quite similar to pre-training values (Table 2).

The average pre-training distance traveled in the 6MWT was 390.80 ± 78.62 m, compared to a post-aerobic training value of 419.00 ± 93.68 m. Thus, the distance traveled after the aerobic training increased significantly ($p < 0.05$). There

Table 1. General characteristics in the subjects

	Age (years)	Gender	Height (cm)	Complications
1	42	Male	167.6	diabetes, hypertension, anemia
2	42	Male	162.7	diabetes, hyperlipidemia, anemia, autoimmune disease
3	62	Female	156.7	hypertension, arthritis, anemia, autoimmune disease
4	73	Male	167.4	diabetes, hypertension, anemia
5	47	Female	154.3	hyper-tension, anemia
6	34	Female	154.3	diabetes, hypertension, anemia, autoimmune disease, tuberculosis
7	62	Female	146.6	diabetes
8	65	Male	171.2	diabetes, hypertension, anemia, autoimmune disease, spinal stenosis
9	63	Female	149.9	diabetes, hypertension, arthritis, anemia,
10	75	Female	150.1	hypertension, arthritis

Table 2. Pre- and post-training on body composition and knee joint muscle function

Variable	Pre-training	Post-training
Body composition		
Weight (kg)	59.6±11.8	59.8±11.4
Muscle mass (kg)	22.7±4.4	22.5±4.1
Body fat mass (kg)	17.2±7.0	17.7±6.8
Fat percentage (%)	28.2±6.8	29.0±7.1
Body mass index (%)	23.9±4.5	23.8±4.5
Muscle function of knee joint		
Right knee extension (peak torque)	50.4±25.3	51.9±24.2
Right knee flexion (peak torque)	23.5±13.3	26.0±11.8
Left knee extension (peak torque)	45.7±26.4	44.5±24.4
Left knee flexion (peak torque)	23.6±15.7	23.1±12.9

No significant difference between pre- and post-training

were no significant changes in resting metabolic rate, lactate threshold, VO_{2max}, or QOL subscale scores. However, each of these variables increased after training (Table 3).

Table 3. Pre-and post-training on physical performance and QOL

Variable	Pre-training	Post-training
6MWT (m)	390.8±78.6	419.0±93.7*
RMR (kcal/day)	895.2±272.4	977.8±396.7
LT (mL/min)	703.8±450.6	738.2±421.5
VO_{2max} (mL/min)	965.0±439.8	993.2±385.7
QOL (score)	1,392.0±494.2	1,596.9±647.8

*$p < 0.05$, 6MWT: six-minute walk test, RMR: resting metabolic rate, LT: lactate threshold, VO_{2max}: maximum oxygen uptake QOL: quality of life

DISCUSSION

There are no known data concerning physical fitness and training tendency in Korean HD patients, but similar data from other countries including the U.S. have showed 45% of dialysis patients seldom training, and only 8% of patients among entirety HD patients did training at least once a week[6)].

In this study, we observed that aerobic training sessions held during dialysis were associated with or maintained or increased physical performance, QOL, control of body composition and muscle function of the knee joint, and increased safe participation in physical activity.

Muscle wasting is common in HD patients and concerns with rose morbidity and mortality[22)]. Muscle wasting is caused by a variety of reasons and process begins early in the disease[23, 24)]. The resistance training of high-intensity was to improve the muscle strength of HD patients[25, 26)]. Similar trials[27, 28)] showed to improve muscle strength by regimens with lower-intensity strength training. Resistance training highly increases metabolism of protein synthesis, leading to increased cross-sectional volume of muscle fibers. In contrast, another study was no changes of lower extremity strength following six weeks of dialysis period[29)]. However, this is not unpredictable considering that aerobic training is not the preferred intervention for improving muscle strength[6)]. In comparison, aerobic training leads to the depletion of free intramuscular amino acids. While aerobic training alone is not enough to activate hypertrophy, it can maintain skeletal muscle mass[29)]. In the our study, there were no significant change on body composition and muscle function of the knee joint. However, each of these variables was quite similar between before and after-training (97.4–103.0% of the respective pre-training values).

This study used the 6MWT, because it is most commonly used test to estimate physical performance, is easy to use, inexpensive, and is representative of daily activities[30]. This test is widely used in patients with cardiac and lung diseases, but its application in HD patients in clinical research is often limited. The average distance achieved in the 6MWT in the pre-training phase was comparable to that achieved in other studies evaluating HD patients[3, 25, 31]. After aerobic training, the distance covered in the 6MWT increased significantly indicating considerable improvement in physical endurance. These findings were coherent with previous study observed an improve of physical performance in patients undergoing dialysis according to the 6MWT after 20 weeks of training[31]. In the our study, there were no significant changes on resting metabolic rate, lactate threshold, VO_{2max}, or QOL, although each of these variables tended to increase after training. HD patients was can significantly increase their VO_{2max} 17–23% by performing aerobic training during dialysis[27]. In contrast, a little studies reported no significantly changes of VO2max following aerobic training, for that reason attributed to prescribing low intensity[32] or short duration aerobic training[33], Several studies of training in HD patients have used SF 36[34] scores as a measurement of QOL. Improved QOL have been presented after aerobic training of 3–5 months[3]. These findings suggest the benefit of a supervised training program for improvement of physical performance and QOL.

People who persistently have a sedentary lifestyle have a greater risk of adverse cardiac events than those who progressively improve their physical activity level[35–38]. In comparison with risks associated with vigorous activities, risk of accidental heart problem in light to moderate intensity activities is lower. Thus, training according to these recommendations incurs a lower cardiovascular risk than vigorous training. As required training test before starting a low-intensity physical activity program would constitute a substantial barrier to participation for many patients and could consequently contribute to an increased risk of remaining sedentary. Pre-training testing is unnecessary, because the recommendations are for gradually increasing low-intensity activity and because the recommendations are made according to the individual's ability with regard to chronic conditions and lower energy levels[34]. In our study, patients were willing to participate in 95% of the training sessions, and the goal of 30 minutes of tolerance to training was achieved by patients around the fourth week. No relevant clinical complications occurred during training; there was only one instance of absence without leave, with a resumption of training at the next dialysis session.

In summary, aerobic training during dialysis sessions is a safe and tends to be associated with improvements in physical performance and QOL. It also contributes to the maintenance of body composition and muscle function of the knee joint in HD patients. Therefore, aerobic training can increase participation in physical activity and appears to be a safe approach to initiating training. Further research is required to resolve the composition of interventions including type, duration, intensity, frequency and these data will require confirmation in samples with a larger number of patients.

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REFERENCES

1) Mula-Abed WA, Al Rasadi K, Al-Riyami D: Estimated glomerular filtration rate (egfr): a serum creatinine-based test for the detection of chronic kidney disease and its impact on clinical practice. Oman Med J, 2012, 27: 108–113. [Medline] [CrossRef]
2) Zhang QL, Rothenbacher D: Prevalence of chronic kidney disease in population-based studies: systematic review. BMC Public Health, 2008, 8: 117. [Medline] [CrossRef]
3) Painter P, Carlson L, Carey S, et al.: Physical functioning and health-related quality-of-life changes with exercise training in hemodialysis patients. Am J Kidney Dis, 2000, 35: 482–492. [Medline] [CrossRef]
4) Suh MR, Jung HH, Kim SB, et al.: Effects of regular exercise on anxiety, depression, and quality of life in maintenance hemodialysis patients. Ren Fail, 2002, 24: 337–345. [Medline] [CrossRef]
5) Knight EL, Ofsthun N, Teng M, et al.: The association between mental health, physical function, and hemodialysis mortality. Kidney Int, 2003, 63: 1843–1851. [Medline] [CrossRef]
6) Wang XH, Mitch WE: Mechanisms of muscle wasting in chronic kidney disease. Nat Rev Nephrol, 2014, 10: 504–516. [Medline] [CrossRef]
7) Johansen KL: Physical functioning and exercise capacity in patients on dialysis. Adv Ren Replace Ther, 1999, 6: 141–148. [Medline]
8) Diaz-Buxo JA, Lowrie EG, Lew NL, et al.: Quality-of-life evaluation using Short Form 36: comparison in hemodialysis and peritoneal dialysis patients. Am J Kidney Dis, 2000, 35: 293–300. [Medline] [CrossRef]
9) Hörl MP, Hörl WH: Hemodialysis-associated hypertension: pathophysiology and therapy. Am J Kidney Dis, 2002, 39: 227–244. [Medline] [CrossRef]
10) Johansen KL, Shubert T, Doyle J, et al.: Muscle atrophy in patients receiving hemodialysis: effects on muscle strength, muscle quality, and physical function. Kidney Int, 2003, 63: 291–297. [Medline] [CrossRef]
11) Macdonald JH, Phanish MK, Marcora SM, et al.: Muscle insulin-like growth factor status, body composition, and functional capacity in hemodialysis patients. J Ren Nutr, 2004, 14: 248–252. [Medline] [CrossRef]
12) Sakkas GK, Ball D, Mercer TH, et al.: Atrophy of non-locomotor muscle in patients with end-stage renal failure. Nephrol Dial Transplant, 2003, 18: 2074–2081. [Medline] [CrossRef]
13) Workeneh BT, Mitch WE: Review of muscle wasting associated with chronic kidney disease. Am J Clin Nutr, 2010, 91: 1128S–1132S. [Medline] [CrossRef]
14) Huang CX, Tighiouart H, Beddhu S, et al.: Both low muscle mass and low fat are associated with higher all-cause mortality in hemodialysis patients. Kidney Int, 2010, 77: 624–629. [Medline] [CrossRef]
15) Marrades RM, Roca J, Campistol JM, et al.: Effects of erythropoietin on muscle O2 transport during exercise in patients with chronic renal failure. J Clin Invest, 1996, 97: 2092–2100. [Medline] [CrossRef]
16) Cheema B, Abas H, Smith B, et al.: Investigation of skeletal muscle quantity and quality in end-stage renal disease. Nephrology (Carlton), 2010, 15: 454–463. [Medline] [CrossRef]
17) Loehr J, Welsh RP: Spontaneous rupture of the quadriceps tendon and patellar ligament during treatment for chronic renal failure. Can Med Assoc J, 1983, 129: 254–256. [Medline]
18) Moore GE, Painter PL, Brinker KR, et al.: Cardiovascular response to submaximal stationary cycling during hemodialysis. Am J Kidney Dis, 1998, 31: 631–637. [Medline] [CrossRef]
19) Cheema BS, Smith BC, Singh MA: A rationale for intradialytic exercise training as standard clinical practice in ESRD. Am J Kidney Dis, 2005, 45: 912–916. [Medline] [CrossRef]
20) Koufaki P, Mercer TH, Naish PF: Effects of exercise training on aerobic and functional capacity of end-stage renal disease patients. Clin Physiol Funct Imaging, 2002, 22: 115–124. [Medline] [CrossRef]
21) Fitts SS, Guthrie MR: Six-minute walk by people with chronic renal failure. Assessment of effort by perceived exertion. Am J Phys Med Rehabil, 1995, 74: 54–58. [Medline] [CrossRef]
22) Carrero JJ, Chmielewski M, Axelsson J, et al.: Muscle atrophy, inflammation and clinical outcome in incident and prevalent dialysis patients. Clin

Nutr, 2008, 27: 557–564. [Medline] [CrossRef]
23) Heiwe S, Clyne N, Tollbäck A, et al.: Effects of regular resistance training on muscle histopathology and morphometry in elderly patients with chronic kidney disease. Am J Phys Med Rehabil, 2005, 84: 865–874. [Medline] [CrossRef]
24) Clyne N, Esbjörnsson M, Jansson E, et al.: Effects of renal failure on skeletal muscle. Nephron, 1993, 63: 395–399. [Medline] [CrossRef]
25) Headley S, Germain M, Mailloux P, et al.: Resistance training improves strength and functional measures in patients with end-stage renal disease. Am J Kidney Dis, 2002, 40: 355–364. [Medline] [CrossRef]
26) Nindl BC, Headley SA, Tuckow AP, et al.: IGF-I system responses during 12 weeks of resistance training in end-stage renal disease patients. Growth Horm IGF Res, 2004, 14: 245–250. [Medline] [CrossRef]
27) Ridley J, Hoey K, Ballagh-Howes N: The exercise-during-hemodialysis program: report on a pilot study. CANNT J, 1999, 9: 20–26. [Medline]
28) Oh-Park M, Fast A, Gopal S, et al.: Exercise for the dialyzed: aerobic and strength training during hemodialysis. Am J Phys Med Rehabil, 2002, 81: 814–821. [Medline] [CrossRef]
29) Moug SJ, Grant S, Creed G, et al.: Exercise during haemodialysis: West of Scotland pilot study. Scott Med J, 2004, 49: 14–17. [Medline]
30) Brooks D, Solway S, Gibbons WJ: ATS statement on six-minute walk test. Am J Respir Crit Care Med, 2003, 167: 1287. [Medline] [CrossRef]
31) Parsons TL, Toffelmire EB, King-VanVlack CE: Exercise training during hemodialysis improves dialysis efficacy and physical performance. Arch Phys Med Rehabil, 2006, 87: 680–687. [Medline] [CrossRef]
32) Goldberg AP, Geltman EM, Hagberg JM, et al.: Therapeutic benefits of exercise training for hemodialysis patients. Kidney Int Suppl, 1983, 16: S303–S309. [Medline]
33) Akiba T, Matsui N, Shinohara S, et al.: Effects of recombinant human erythropoietin and exercise training on exercise capacity in hemodialysis patients. Artif Organs, 1995, 19: 1262–1268. [Medline] [CrossRef]
34) Nelson ME, Rejeski WJ, Blair SN, et al. American College of Sports Medicine American Heart Association: Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Circulation, 2007, 116: 1094–1105. [Medline] [CrossRef]
35) Thompson PD, Franklin BA, Balady GJ, et al. American Heart Association Council on Nutrition, Physical Activity, and Metabolism American Heart Association Council on Clinical Cardiology American College of Sports Medicine: Exercise and acute cardiovascular events placing the risks into perspective: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism and the Council on Clinical Cardiology. Circulation, 2007, 115: 2358–2368. [Medline] [CrossRef]
36) Ponngeon O, Chaunchaiyakul R, Vareesangthip K, et al.: Home-based walking program increases leg muscle strength in hemodialysis patients. J Phys Ther Sci, 2011, 23: 345–348. [CrossRef]
37) Cho H, Sohng KY: The effect of a virtual reality exercise program on physical fitness, body composition, and fatigue in hemodialysis patients. J Phys Ther Sci, 2014, 26: 1661–1665. [Medline] [CrossRef]
38) Shi ZM, Wen HP, Liu FR, et al.: The effects of tai chi on the renal and cardiac functions of patients with chronic kidney and cardiovascular diseases. J Phys Ther Sci, 2014, 26: 1733–1736. [Medline] [CrossRef]